Effects of Disturbance on Populations of Marine Mammals

Erica Fleishman, Ph.D., Principal Investigator
John Muir Institute of the Environment
The Barn
One Shields Ave.
University of California
Davis, CA 95616
phone: (530) 754-9167 fax: (530) 754-9141 email: efleishman@ucdavis.edu

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LONG-TERM GOALS

The long-term goal of this project is to develop transferable models of the population-level effects of anthropogenic and natural disturbances on marine mammals. Disturbances can affect the physiology or behavior of animals, which in turn may lead to changes in demographic rates and viability. Population-level effects of disturbance also may cascade among species. However, it has proven difficult to identify and model the mechanisms by which individual-level responses to disturbance might propagate to the population level. A clear, quantitative understanding of such mechanisms will inform assessment of trade-offs among potential responses of species to environmental changes and diverse human activities.

OBJECTIVES

- Translate conceptual models of effects of disturbance on behavior or physiology, health, vital rates, and population dynamics into quantitative models for different taxa.
- Prioritize data collection for estimation of population-level effects of different types of disturbance on marine mammals with different life-history attributes.
- Examine the extent to which collection of high-priority data currently is feasible in terms of time, money, and technology.
- Examine inferences about effects of disturbance on individuals and populations that can be drawn on the basis of limited empirical information.
- Compare inferences about population-level effects of disturbance that are based on extensive empirical data to those based on expert elicitation.

APPROACH

Work will be conducted by a multidisciplinary group of approximately 15 individuals, many of whom participated in an earlier phase of the work. New participants will have expertise on subjects including structured decision-making, analyses of expected value of information, and expert elicitation. The group likely will hold four face-to-face workshops of three days each over the project period. Meetings

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will be held in locations that minimize travel time and expenses for the greatest proportion of participants and maximize opportunities to interact with other groups interested in the work and its application. Project oversight is provided by a five-member steering committee [Dan Costa (University of California, Santa Cruz), Erica Fleishman, John Harwood (University of St. Andrews), Scott Kraus (New England Aquarium), and Mike Weise (Office of Naval Research)].

WORK COMPLETED

The working group convened 10–12 July 2012 at the New England Aquarium in Boston, Massachusetts. At their home institutions, subsets of the working group are either completing models initiated relatively recently or expanding on previous work to increase its generality. Efforts are underway to model the population-level effects of disturbances on five marine-mammal taxa: southern elephant seals (*Mirounga leonina*), northern elephant seals (*Mirounga angustirostris*), coastal populations of bottlenose dolphins (*Tursiops* spp.), northern right whales (*Eubalaena glacialis*), and Blainville's beaked whales (*Mesoplodon densirostris*). During the July meeting, points of contact for ongoing analyses or deliverables led discussions of the current status of their work and how the group as a whole can contribute to or support the aims of each effort. We currently aim to achieve the following.

- Define the functional relations between health and survival and between health and reproductive rate of northern elephant seals.
- Define the functional relation between maternal health and pup survival in southern elephant seals and link results to complementary models describing the relation between foraging and health.
- Test whether different methods for identifying drift dives by elephant seals and estimating drift rates yield equivalent results.
- Estimate changes in lipid content of elephant seals that are foraging at sea. Test whether foraging location, condition when the animal departs from the colony, and environmental covariates affect lipid gain, and whether animals gain lipids at different rates during various phases of an approximately eight-month trip.
- Estimate population-level effects of disturbance on bottlenose dolphins in Sarasota Bay, Florida. In the short term, identify data and ongoing analyses necessary for these estimates (see details below).
- Simulate the spatial distribution, social structure, behavioral time budgets, and response to disturbance of coastal bottlenose dolphins in the Moray Firth, Scotland.
- Fit an existing simulation model of bottlenose dolphin behavior to data from Doubtful Sound, New Zealand.
- Quantify the relation between health of individual right whales and entanglement with fishing gear or sublethal collisions with ships.
- Quantify the effects of natural and anthropogenic stressors on the health of individual right whales. Apply the modeled relation between health and survival to test five assumptions. First, photographic observations of individuals reliably measure their health. Second, uncertainty surrounding estimates of health decreases as the number of observations increases. Third, at the population level, health decreases during periods of food limitation. Fourth, disturbance reduces

individual fecundity by increasing the interval between reproductive events (birth of calves). Fifth, probability of survival increases as health improves.

- Develop a model structure and provide an initial estimate of the population-level effects of sonar on Blainville's beaked whales in the Bahamas.
- Develop a model of the energetic requirements of adult female beaked whales for survival and reproduction that can be linked with dose-response curves under development for Blainville's beaked whales in the Bahamas.
- Outline the conceptual model linking short-term changes in behavior and physiology of individuals to long-term population level effects. Use southern elephant seals to provide a simple example of the feasibility of quantitative modeling.

Population-level effects of disturbance on bottlenose dolphins in Sarasota Bay, Florida
Researchers began collecting data on bottlenose dolphins in Sarasota Bay, Florida, in 1970. Eight databases contain information that may inform models of population-level effects of disturbance: sightings (mark-recapture), female reproductive history, body condition and morphometrics, strandings, health, fish survey, behavioral follows, and acoustics. Some databases cover longer periods of time, and some data-collection techniques have changed over time to accommodate shorter-term studies. Two databases, health and body condition and morphometrics, contain the data collected during capture-release health assessments. Assessments are conducted one or more times per year to meet the needs of shorter-term studies.

Discussions with researchers at the Mote Marine Laboratory and their colleagues in July 2012 suggested that the health assessment data may provide a foundation for an unusual and productive case study. No other bottlenose dolphin study provides direct measures of health of individuals, sometimes repeated over the life of the animals. Necropsy and stranding data potentially allow for examination of metrics of health when animals are ill or have died. Work to develop a visual index of health could facilitate a verified metric of health on the basis of photographs. From photographs, one then could analyze vital rates as a function of health over shorter periods of time. Depending on the time period for which photographs and behavioral data are available, it may be possible to link individual time-activity budgets with health. Estimates of vital rates from models of population-level effects of disturbance could be used in collaborative efforts to model population dynamics.

Expert elicitation of population-level effects of disturbance on North Atlantic right whales
Also in July 2012, the working group brainstormed questions about population-level effects of disturbance on right whales that potentially could be addressed with expert elicitation. As a collaborator noted, questions that resulted from group brainstorming could fit in one of five categories, each of which would be answered with different methods.

- Questions about estimation of model parameters. Expert panels can be used to estimate parameters. This is a clear objective and one of the easiest to achieve with expert panels.
- Hypotheses about different ways in which the modeled system might function. One typically works with the panel to clarify a full set of plausible alternative hypotheses. Each hypothesis must be sufficiently clear to translate into testable predictions. That clarification process may require estimating some parameter values. If experts have different degrees of belief in alternative hypotheses at the outset, those beliefs can become priors in a Bayesian analysis.

- Properties of a model. For example, "What are the relative effects of fecundity and juvenile survival on population dynamics?" One might need experts to estimate prior distributions for fecundity and juvenile survival (i.e., treat these as questions about estimation of model parameters), but as phrased, the question is about an analytical model.
- Decision analysis. For example, "For all unknowns for which priors are included in models of response to disturbance, what is the expected value of a given decrease in uncertainty (expected value of information)?" In this case, experts establish the priors.
- Properties of a monitoring system. For example, "What is the relative contribution of different types of observations or metrics to the composite measure of health?" If one is unable to measure a modeled response variable directly, then the questions are about monitoring or measurable attributes and the extent to which surrogate measures of the response variable are reliable. In this case, one should try to reframe questions so they fit into the first two categories. Otherwise, one is simply asking experts for their opinion and formal elicitation is not useful.

The group's next task is to cull and refine the questions. A second collaborator said, "Elicitation works best when the decision context is known. For example, we could explore plausible estimates for a range of parameters for vital rates for a species, without any other expert input. If we find that the vital rate estimates within plausible ranges do not affect any decisions we may take, then we may decide it's not worth wasting experts' time, and move on to another topic." This collaborator suggested the group follow three steps.

- Revise the existing questions or identify new questions that address unambiguous, crisp, well-specified questions about issues of fact, or about model structures.
- Identify a subset of those questions that make a difference for decision-making [perhaps through value-of-information analyses].
- Gather the experts, either electronically or physically, and query them with an appropriate question format and structure.

A third collaborator commented that the group must determine the type of model or analysis we wish to inform with expert knowledge. Without a clear idea of how the information will be used we risk asking the wrong questions and then having to go back to the experts again (which is fatiguing for all). Once we understand the relative effects of different stressors on the status of the population (e.g., health, population size, probability of persistence), we can model (on the basis of methods such as stochastic dynamic programming) the effect of the stressors on the population and ultimately the effect of various actions to mitigate the effects of these stressors through time and space.

As next steps, Kraus, Doug Nowacek, four to five collaborators with expertise in expert elicitation, and Fleishman will work together to identify a small number of questions that, if answered, would inform decision-making and that cannot be answered without at least some expert knowledge. We will develop methods for the elicitation itself, establish criteria for expertise relative to the question, and invite participants (the experts). The elicitation may be initiated during a November, 2012 meeting of the right whale consortium.

RESULTS

Data from group follows of coastal bottlenose dolphins likely are insufficient to reliably infer motivational states and health of individuals. Participants previously built a simulation model to inform management of interactions between bottlenose dolphins and boats in the Moray Firth, Scotland. The model recently was applied to data from Doubtful Sound, New Zealand that were collected during scan-samples of focal groups of dolphins from 2000 through 2002. Initial simulations suggested that the motivations, including health, of individual animals over time could be estimated accurately on the basis of focal-follow data. However, when model parameters were estimated with data from Doubtful Sound, the predicted activity budgets generated by the model were not biologically realistic. For example, animals were predicted to spend almost all of their time travelling. Forcing the groups to travel for one time step before displaying any other behavior improved model fit, but results remained unrealistic. Successful parameterization required information on the spatial distribution of behaviors and the health of individuals (i.e., respiration rate). Telemetry data may be more useful for this purpose than group follows because the telemetry data can provide information on behavioral state, movement, and responses to sound or other disturbances and potentially on direct measures of health.

APPLICATIONS

Multiple public and private sectors wish to understand whether observed changes in animals' behavior or physiology affect probabilities of persistence. Subsistence hunters also wish to understand whether short-term changes in behavior may affect long-term spatial distributions of animals. The concept that behavioral responses to disturbance are not necessarily surrogate measures of population-level responses is widely understood. However, without tractable methods for quantifying population-level effects, most sectors will be restricted to estimating exposure of individual animals to disturbances or changes in habitat quantity or quality. Thus, improved understanding of transfer functions might help to guide research and management, and to project how marine mammals will respond to alternative scenarios of human activities, from those that produce sound to climate change to changes in human density and distributions.

RELATED PROJECTS

Kraus, Moretti, and Thomas have received ONR support for models of effects of disturbance on individual species. Their efforts are integral to the success of this award.

An ONR award supporting the first phase of the working group's collaboration will conclude in December, 2012.

Fleishman is leading a project on cumulative effects of underwater anthropogenic sound on marine mammals for BP Exploration. To date, the cumulative-effects project has focused on effects at the individual level. The ONR-sponsored project may provide a means for evaluating how effects might transfer to the population level.